

Introductory comments to the Archive version of the paper

“Can We Detect Tachyons Now?”

The present paper is placed in this Archive to call attention of a large community of experimenters to the fact that there exists a sound theoretical prediction that the light barrier may be overcome in relatively simple experiments. The paper acquaints the reader with the situation in an abbreviated and general form, and outlines the main empiric conditions that should exist or be created in the considered case. It should be emphasized that the mentioned prediction closely relates to the theoretical prediction that gravitational waves exist, since in terms of general relativity these two predictions belong to the same family. Let us also note that massive and very expensive experiments to search for these waves have already been performed, some others are being prepared, and new ones are planned.

Informative remarks

The present version slightly differs from the published one [Acta Physica Polonica **B31** (2000) 523]. Namely, we have here small modifications (on p. 9) and extensions (on pp. 2, 3, and 9), which are marked by underlining. Note that the title page of the paper carries here number 2.

CAN WE DETECT TACHYONS NOW?⁰

J. K. KOWALCZYŃSKI

Institute of Physics, Polish Academy of Sciences,

Al. Lotników 32/46, 02-668 Warsaw, Poland

e-mail: jkowal@ifpan.edu.pl

An exact solution of the Einstein–Maxwell equations enables us to construct a hypothesis on the production of tachyons. The hypothesis determines the kinematical relations for the produced tachyon. It also makes possible to estimate the empiric conditions necessary for the production. These conditions can occur when nonpositive subatomic particles of high energy strike atomic nuclei other than the proton. This suggests how experiments to search for tachyons can be performed. According to the hypothesis properly designed experiments with air showers or with the use of the strongest colliders may be successful. Failure of the air shower experiments performed hitherto is explained on the grounds of the hypothesis.

PACS numbers: 14.80.Kx, 25.90.+k

⁰Presented at the XXVI Mazurian Lakes School of Physics, Krzyże, Poland, September 1–11, 1999. This contribution is a fragment of the presentation. The full text can be found in the LANL Archives (<http://xxx.lanl.gov/hep-ph/9911441>), or in *Acta Physica Slovaca* **50** (2000) 381–395.

1. Introduction

The subject of this note is a hypothesis on the tachyon creation, based on an exact solution of the Einstein–Maxwell equations. Details are given in Ref. [1], where this solution is referred to as Ω_1 . The solution yields a realistic picture of the tachyonic phenomenon. This fact can therefore be regarded as an indication on the part of general relativity that the tachyon exists in nature, considering the analogy to many theoretical predictions that found later empirical confirmation. Our solution invariantly determines a spacetime point (event) that can be interpreted as a point of creation of the tachyon; and this makes the construction of the hypothesis possible. According to our solution the tachyon produces an electromagnetic field bounded by the tachyon’s shock wave. In the generated spacetime the gravitational field, i.e. the direct cause of spacetime curvature, does not exist autonomously but is only an “emanation” of the electromagnetic field. Thus, even if the latter field were by many orders of magnitude stronger than the strongest electromagnetic fields observed so far, the spacetime curvature would be completely negligible. This and the fact that the tachyon’s shock wave is electromagnetic mean that our solution is proper to describe an *ionizing tachyon belonging to the microworld*. The hypothesis is presented in Section 2.

Various experimental searches for ionizing tachyons have been described in a number of papers. A large majority of them is cited in Refs. [2–7]. The experiments were of low and high energy type. Failure of the low energy experiments is explicable by our hypothesis, as will be seen in Sections 2 and 3. In the high energy experiments air showers were exploited; and many of the experiments have reported detection of tachyon candidates but as statistically insignificant data. A single possibly positive result [8] has also been rejected [2]. This situation has presumably disheartened most experimenters (the last relevant record in the Review of Particle Properties [6] is dated 1982 [5]), though some efforts were still made [7]. According to our hypothesis, however, air shower (and accelerator) experiments may be successful and they are discussed in Section 3.

2. The hypothesis

The hypothesis says that the tachyon is produced when a neutral subatomic particle of sufficiently large rest mass (further called the generative particle) is placed in the strong electromagnetic field described just below (further called the initiating field). The generative particle is then annihilated giving birth to the tachyon.

In this section all the quantities, relations, and situations are presented in terms of the *proper* reference frame of the generative particle, with the use of the Lorentzian coordinates x, y, z , and t (further t does not appear explicitly). We assume that the origin $x = y = z = 0$ of the spacelike coordinates is at the centre of the generative particle.

Let \mathbf{E} and \mathbf{H} be accordingly the electric and magnetic three-vectors of the initiating field, and let their components be denoted by E_i and H_i . There are two types of the initiating field:

$$\begin{aligned} E_x &= \mp AB|w|, & E_z &= \pm 2jABC, & H_y &= \mp jAB|w|, \\ E_y &= H_x = H_z = 0, \end{aligned} \tag{1}$$

and

$$\begin{aligned} E_y &= \pm AB|w|, & H_x &= \mp jAB|w|, & H_z &= \pm 2ABC, \\ E_x &= E_z = H_y = 0, \end{aligned} \tag{2}$$

where

$$\begin{aligned} j &= \pm 1, & |w| &> 1, & jw &< 0, \\ A &> 0, & B &:= (5w^2 - 4)^{-1/2} \geq 0, & C &:= (w^2 - 1)^{1/2} > 0, \end{aligned} \tag{3}$$

and where w is a dimensionless parameter determining the tachyon's velocity. Then, according to the hypothesis, the tachyon produced in the generative particle and fields (1)–(3) moves along a semi-axis z with a velocity cw , c being the speed of light in vacuum. The discrete parameter j plays an important role in the

exact theory based on our solution [1]. Note that in accordance with the known properties of the spacelike world lines we may have $|w| = \infty$.

From relations (1)–(3) we see that

$$\mathbf{E} \perp \mathbf{H}, \quad |\mathbf{E}| \neq |\mathbf{H}|, \quad |\mathbf{E}||\mathbf{H}| \neq 0, \quad (4)$$

and that $A = |\mathbf{E}| > |\mathbf{H}|$ in the case (1) and $A = |\mathbf{H}| > |\mathbf{E}|$ in the case (2).

Let the tachyon produced in the initiating field (1) and (3) be called the *e-tachyon* (predominance of the electric field) and that produced in the initiating field (2) and (3) be called the *m-tachyon* (predominance of the magnetic field). The e- and m-tachyons differ since they generate different electromagnetic fields.¹

Let U be defined as follows: $U = |\mathbf{H}|^{-1}|\mathbf{E}|$ in the case (1) and $U = |\mathbf{E}|^{-1}|\mathbf{H}|$ in the case (2). Thus, by relations (1)–(3), we have $U > 1$ and

$$U^2 = 5 - 4w^{-2}, \quad (5)$$

i.e.

$$1 < U^2 \leq 5. \quad (6)$$

If the angle between the tachyon path (a semi-axis z) and the longer three-vector of the initiating field is denoted by α , then

$$\sin \alpha = U^{-1}. \quad (7)$$

By generating perpendicular electric and magnetic fields we determine empirically the directions in space. If these fields satisfy the condition (6), then, according to the hypothesis, for each type of tachyons under consideration Eqs. (5) and (7) determine four variants of the complete kinematical conditions for the produced tachyon. The existence of four variants results from relations (1)–(3) and (7). Namely, there are double signs of the nonzero components E_i and H_i ,

¹On the analogy of the subluminal microworld, in which only one type of charges (electric) is known, we may suspect that only one type of our tachyons exists in nature (i.e. either the e-tachyons or the m-tachyons), but today we do not yet know which one. Thus, for safety, both types should be considered.

a double sign of j (i.e. a double sign of w since $jw < 0$), and $\sin\alpha = \sin(\pi - \alpha)$, i.e. we apparently have eight variants, but each one of these three items depends on two others.

In order to determine the principal empiric conditions for the tachyon production, we should also know the quantity A and the rest mass M of the generative particle. I am able to estimate only their lower limits [1].

In the case of A , we get

$$A \gtrsim 6.9 \times 10^{17} \text{ esu/cm}^2 \text{ or oersted.} \quad (8)$$

In the case of M , I am able to estimate its lower limit only when $|w| \cong 1$ (thus for $U \cong 1$; note that $|w| > 1$ and $U > 1$), i.e. when the produced tachyon is very “slow” in the proper reference frame of the generative particle.² Laborious calculation [1] gives

$$M \gtrsim 75 \text{ GeV}/c^2. \quad (9)$$

Our hypothesis concerns the production of the tachyons generating convex spacetimes; and such tachyons can exist autonomously. Let us call them *principal tachyons*. Each principal tachyon may be accompanied with an arbitrary (formally) number of tachyons generating concave spacetimes. The latter tachyons cannot exist autonomously but they can exist if they form a “star of tachyons” together with a principal tachyon. Let us call them *accompanying tachyons*. All the tachyons forming their “star” are born at one event (common creation point). Details are given in Ref. [1], and briefly in Ref. [9].

3. Comments on the empiric possibilities

The production conditions determined by our hypothesis can occur in high energy collisions with atomic nuclei other than the proton. In such collisions we can locally obtain the conditions (4) (for details see Ref. [1]) and the relativistic

²Such a tachyon can, however, be observed as considerably faster than light if the sense of its velocity is opposite in the laboratory reference frame to the sense of the generative particle velocity (sufficiently high but subluminal of course); cf. remarks on the backward tachyons in Section 3.

intensification of the electromagnetic fields of nuclei necessary to satisfy the condition (8). It is easy to calculate that this intensification gives $U \cong 1$, i.e. the condition (9) holds. Thus the gauge boson Z^0 is the lightest known candidate for the generative particle. Though the mean life of this boson is very short, the production conditions can be satisfied. In fact, if a subatomic particle of sufficiently high energy strikes a nucleon included in an atomic nucleus and produces the boson Z^0 , then *in statu nascendi* this boson moves with respect to the nucleus (its remainder) with a velocity that sufficiently intensifies the electromagnetic field. In particular, neutrons present in nuclei should be struck by neutral particles, while protons by negatively charged ones. In the case of nuclei so large that we may speak of peripheral nucleons, the collision with such a nucleon (“tangent” collision) is the most effective. Note that the principal m-tachyon is produced *only* when the proton in the ^2H , and perhaps ^3H , nucleus is appropriately struck. When designing controlled collisions, we can practically use only electrons or antiprotons as the striking particles. In all the mentioned collisions we have $U \cong 1$ and therefore, by Eq. (7), the striking particle and the produced principal tachyon have practically the same direction of motion, but according to our theory they may have different senses [1]. In the case of opposite senses for brevity we shall be speaking about *backward tachyons*, and in the case of the same senses about *forward tachyons*. This nomenclature relates to the principal tachyons only.

The collisions described above should occur in air showers and can be realized in or at some high-energy colliders. Let us discuss these two cases in terms of the *laboratory* (and thus the *earth*) reference frame.

The collisions producing tachyons should occur in the air showers initiated by cosmic (primary) particles of energy of $\sim 10^{13}$ eV and greater (events above 10^{20} eV have been reported [10]). Thus our hypothesis justifies air shower experiments designed to detect tachyons. The time-of-flight measurement experiments (e.g. described in Refs. [5,11,12]) are obviously more credible than the experiments described and/or cited in Refs. [2–4,7,8] and designed only to detect

charged particles preceding the relativistic fronts of air showers, though a massive-measurement experiment of the latter type performed by Smith and Standil with the use of detector telescopes [13] has had great weight. Tachyon candidates were observed in the time-of-flight experiments [5,11,12] and in many “preceded front” ones including that described in Ref. [13], but these unlucky candidates were sunk in backgrounds and/or statistics. Thus, formally, we have to consider the results as negative. In the light of our hypothesis, however, properly designed experiments with air showers (“poor man’s accelerator” [12]) are worth repeating, the more so as they are relatively inexpensive.

Let us note that no forward tachyons can be observed in any air shower experiment performed in the terrestrial reference frame, since these tachyons cannot practically precede the shower fronts. In fact, it is easy to calculate from relations (5), (8), and from the relativistic law of addition of velocities that the forward e-tachyons produced in collisions with nuclei ^{40}Ar can move in this reference frame with speeds not greater than $\sim 1.0000008c$. In the case of nuclei ^{16}O or ^{14}N , or ^2H in the case of production of the forward m-tachyons, the upper speed limit is still lower. On the other hand, some tachyons accompanying those “slow” forward tachyons may travel considerably faster than light towards the ground. This is possible provided that the angle, denoted by ψ for short, between the motion directions of such a forward tachyon and of its accompanying tachyon is sufficiently large.³ Unfortunately, these fast accompanying tachyons cannot be observed in typical “preceded front” experiments since they escape from the showers sidewise. They could be observed in the previous time-of-flight experiments in the cases when the shower axis was largely inclined with respect to the flight corridor of the detector (large ψ).

³In every given reference frame, if a principal tachyon moves with a speed $|W| < \infty$ and if the angle ψ between the velocity W and velocity V of a tachyon accompanying this principal one is, for simplicity, smaller than $\pi/2$, then $|V| \leq c|W|/[c\cos\psi + (W^2 - c^2)^{1/2}\sin\psi]$ and there is a lower limit for ψ , namely $\arccos(c/|W|) < \psi < \pi/2$ in the case under consideration. Of course $|V| > c$ and $|W| > c$.

The described situation seems to explain the poor statistics obtained from the previous experiments, and suggests how to design new air shower experiments to search for tachyons. It seems that the best solution would be an *apparatus with many time-of-flight corridors of various directions*. In order to increase efficiency, such an apparatus should be possibly close to the region of tachyon production (mountains? balloons?). To increase credibility, simple air shower detectors (placed on the ground for convenience) can additionally be used. They should be far from the main apparatus (its projection on the ground) to act when ψ is large, i.e., when the registered showers are remote or largely inclined. If some tachyon flights through the main apparatus coincide with the signals from some of the additional detectors, then we get stronger evidence that tachyons are produced in air showers. The use of the main apparatus alone should also give us valuable results without detecting any showers.

The appearance of tachyon candidates in some previous “preceded front” experiments can be explained as the arrival of tachyons accompanying the backward tachyons. The backward tachyons produced in air showers are slightly faster than $5c/3$ in the terrestrial reference frame. Thus, at sufficiently high altitudes (balloons? satellites?), they should be easily identified as tachyons and the detecting system can be *very simple*.

Failure of the previous air shower experiments may also be explained by the very low deuterium content (cf. the beginning of this section) in the earth’s atmosphere. Indeed, if the principal e-tachyons do not exist in nature but the principal m-tachyons do (cf. Footnote 1), then the probability of production of principal tachyons is very low. Then, however, this probability strongly depends on weather. Roughly speaking, the cloudier the skies the higher the probability. (This also concerns the case of the $5c/3$ backward tachyons when the detecting system must be of course above the clouds.) It seems that the effect of cloudiness has not been taken into account in the experiments performed hitherto. If the principal tachyons are only the m-tachyons, then the efficiency of air shower ex-

periments may be increased by introducing extra deuterium. For instance, we can place the above mentioned apparatus (i.e. that with many time-of-flight corridors) *inside* a large balloon filled with hydrogen and next dispatch the balloon to the region of tachyon production.

In the case of performing tachyon search experiments with the use of accelerators we can choose the striking particles (practically either electrons or antiprotons), the nuclei to be struck, and the energy of collisions. Relations (8) and (9) mean that the strongest colliders should be employed. At present, however, we can only direct a beam of electrons or antiprotons onto a stationary target. This would give us principal tachyons such as in the case of air showers, i.e. forward tachyons so “slow” that indistinguishable as tachyons and backward tachyons slightly faster than $5c/3$. As regards accompanying tachyons, we would have a much better situation since the target can be surrounded with tachyon detectors, e.g. with time-of-flight ones. The fact that tachyon candidates were observed in air shower experiments indicates that there should be no problems with the range of tachyons in the collider experiments. A collider with a high energy beam of atomic nuclei would extend our empiric possibilities. We could then control the observed speeds of backward and forward tachyons and, in consequence, change the observed velocities of the accompanying tachyons. Besides, we could then produce principal m-tachyons (cf. the preceding paragraph), which is impossible in the near future when a stationary target is used. For instance, a beam of electrons of energy of ~ 25 GeV or a beam of antiprotons of energy of ~ 0.1 TeV when colliding with a beam of deuterons of energy of ~ 1 TeV (~ 0.5 TeV/u) or of ~ 0.24 TeV (~ 0.12 TeV/u), respectively, would already realize the production conditions, whereas in the case of the deuterium target the energy of the striking negative particles must be ~ 26 TeV. When using stationary targets to produce principal e-tachyons, we need the striking negative particles of energy of ~ 0.8 TeV for the targets made of heavy nuclei, and of ~ 2 TeV for the targets made of light nuclei.

Let us note that in the experiments designed to detect tachyons the existence of a reference frame preferred for the tachyons should be taken into account. In terrestrial experiments we should therefore analyze the measurements in correlation with the time of the day, and additionally, in long-lasting experiments, with the season of the year. It seems obvious that from this point of view the experiments with the use of colliders are more suitable than those with air showers.

The existence of the reference frame preferred for the tachyons has been considered or postulated by many authors. Most of the relevant literature is cited in Refs. [14–16]. Some ideas are, however, in conflict with empiric data, some others can only be verified by means of tachyons. According to the latter ideas such a frame is imperceptible for bradyons and luxons, which means that this frame is a usual non-preferred inertial reference frame for all the tachyonless phenomena. This is not contradictory to relativity (which has been verified only in the bradyonic and luxonic domains) and is not empirically ruled out since tachyons have not yet been employed. The most natural idea (i.e. when the (local) Minkowski’s spacetime is assumed to be spatially isotropic also for tachyons) has thoroughly been analyzed in Section 3 of Ref. [15]. Following this idea, many authors suggest that the frame in question is that in which the cosmic microwave background radiation is isotropic. If their intuition is correct, then in terrestrial experiments this frame can be revealed only by means of tachyons which are very fast (over $\sim 800c$) in the laboratory reference frame. If, however, the “tachyon corridor” described by Antippa and Everett [17,18] did exist, then “slow” tachyons would be sufficient to reveal it.

REFERENCES

- [1] J.K. Kowalczyński, *The Tachyon and its Fields*, Polish Academy of Sciences, Warsaw 1996.
- [2] J.R. Prescott, *J. Phys.* **G2**, 261 (1976).
- [3] L.W. Jones, *Rev. Mod. Phys.* **49**, 717 (1977).
- [4] P.N. Bhat, N.V. Gopalakrishnan, S.K. Gupta, S.C. Tonwar, *J. Phys.* **G5**, L13 (1979).
- [5] A. Marini, I. Peruzzi, M. Piccolo, F. Ronga, D.M. Chew, R.P. Ely, T.P. Pun, V. Vuillemin, R. Fries, B. Gobbi, W. Gurny, D.H. Miller, M.C. Ross, D. Besset, S.J. Freedman, A.M. Litke, J. Napolitano, T.C. Wang, F.A. Harris, I. Karliner, Sh. Parker, D.E. Yount, *Phys. Rev.* **D26**, 1777 (1982).
- [6] Particle Data Group, Review of Particle Properties, *Phys. Rev.* **D50** (1994) No. 3-I, p. 1811.
- [7] R.W. Clay, *Aust. J. Phys.* **41**, 93 (1988).
- [8] R.W. Clay, P.C. Crouch, *Nature* **248**, 28 (1974).
- [9] J.K. Kowalczyński, *Phys. Lett.* **74A**, 157 (1979).
- [10] T.K. Gaisser, T. Stanev, *Phys. Rev.* **D54**, 122 (1996).
- [11] F. Ashton, H.J. Edwards, G.N. Kelly, *Nucl. Instrum. Methods* **93**, 349 (1971).
- [12] H. Hänni, E. Hugentobler, in *Tachyons, Monopoles, and Related Topics*, ed. E. Recami, North-Holland, Amsterdam 1978, p. 61.
- [13] G.R. Smith, S. Standil, *Can. J. Phys.* **55**, 1280 (1977).
- [14] R. Girard, L. Marchildon, *Found. Phys.* **14**, 535 (1984).
- [15] J.K. Kowalczyński, *Int. J. Theor. Phys.* **23**, 27 (1984).
- [16] J. Rembieliński, *Int. J. Mod. Phys.* **A12**, 1677 (1997).
- [17] A.F. Antippa, A.E. Everett, *Phys. Rev.* **D8**, 2352 (1973).
- [18] A.F. Antippa, *Phys. Rev.* **D11**, 724 (1975).